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NEW PROJECTILE DETECTOR AND STATION CONTROLLER FOR THE DREV AEROBALLISTIC RANGE

G. Drouin

Centre de Recherches pour la Défense
Defence Research Establishment
Valcartier, Québec

BUREAU - RECHERCHE ET DÉVELOPPEMENT
MINISTÈRE DE LA DÉFENSE NATIONALE
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by

G. Drouin

CENTRE DE RECHERCHES POUR LA DEFENSE
DEFENCE RESEARCH ESTABLISHMENT
VALCARTIER
Tel: (418) 844-4271

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ABSTRACT

The outdated equipment of the DREV aeroballistic range, which included a combination of photographic and yaw card stations, is being replaced by a series of 54 new orthogonal photographic ones. Each station uses two point light sources for projecting shadows of the projectile onto orthogonal reflecting panels which are then photographed by two cameras. A short distance uprange of each station, a detector senses the arrival of the projectile and informs a controller which, after a time delay, triggers the light sources. The controllers, tied through a common bus to the operator's console, are used to remotely set the detector gains and the photography time delays, to simulate a projectile arrival and to provide a status of station readiness. This document reports on the projectile detector and the station controller.

RÉSUMÉ

L'équipement désuet du tunnel aérobalistique du CRDV, qui comprenait une combinaison de postes photographiques et de cartons témoins, est en voie de remplacement par une nouvelle série de 54 postes de photographie orthogonale. A chaque poste, sur deux axes perpendiculaires, une source de lumière ponctuelle projette sur un écran perlé une ombre du projectile laquelle est photographiée par une caméra. A une courte distance en amont du poste un détecteur sensible au passage du projectile informe le contrôleur qui, après un intervalle de temps préréglé, déclenche les sources lumineuses. Tous les contrôleurs sont reliés par un bus commun à la console de l'opérateur et chacun règle le gain du détecteur, le retard de photographie, simule la détection d'un projectile et fournit l'état du poste. Ce rapport traite du détecteur de projectiles et du contrôleur de poste.

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1.0 INTRODUCTION

In order to meet its requirements for aeroballistic studies during the next 15 years or so, Defence Research Establishment Valcartier (DREV) has redesigned its aeroballistic range facility, taking advantage of recent progress in electronics and range technologies, to produce more accurate and more reliable aerodynamic data. In particular, the experience gained at the Eglin ARF (Ref. 1) has been very useful in this regard. The DREV aeroballistic range is an instrumented building designed for the measurement of attitude and position of free-flight projectiles as a function of time and distance. The building is an insulated steel-clad concrete structure and is 230 m long with a cross-section area of 37.2 m^2 (Fig. 1). It is heated through electric elements in the concrete floor and the temperature is maintained at 20°C ± 2°C. Projectiles of calibers ranging from 7.62 to 155 mm can be launched from the firing bay located outside the range. A massive blast wall in front of the building stops sabot pieces and minimizes vibration transmitted to the range structure.

In its original configuration, the range instrumentation included 24 orthogonal photographic stations and 76 yaw card stations (Ref. 2). Photography was used for velocity and drag measurements while the signatures in the yaw cards were utilized for position, attitude and roll-angle determination. The effect of the yaw cards on projectile motion was difficult to evaluate and the number of photo stations was not sufficient to provide the information required. At the beginning of the range, four schlieren systems permitted qualitative visualization of the flow around the models.

The new equipment eliminates the need for yaw cards, retains the same flow visualization system and includes a new series of 54 accurate orthogonal photographic stations. Each photographic station (Fig. 2) makes use of two short-duration point light sources which project shadows of the projectile onto two orthogonal reflecting panels (one vertical and one horizontal). Two cameras focussed on the panels photograph the shadows.

A short distance uprange of each station, an infrared radiation screen senses the arrival of the projectile and feeds an impulse to a station controller. After a preset delay (i.e. the time required for the projectile to reach the center of the camera field of view) the controller triggers the two point light sources. The controller is an intelligent apparatus which intercepts, stores and relays information received from the operator for the control of the station equipment and returns station status words when requested. The purpose of this report is to describe the projectile detector and the station controller. The work was performed at DREV between 1979 and 1981 under PCN 21M15, Aeroballistic Studies.

FIGURE 1 - The DREV aeroballistic range

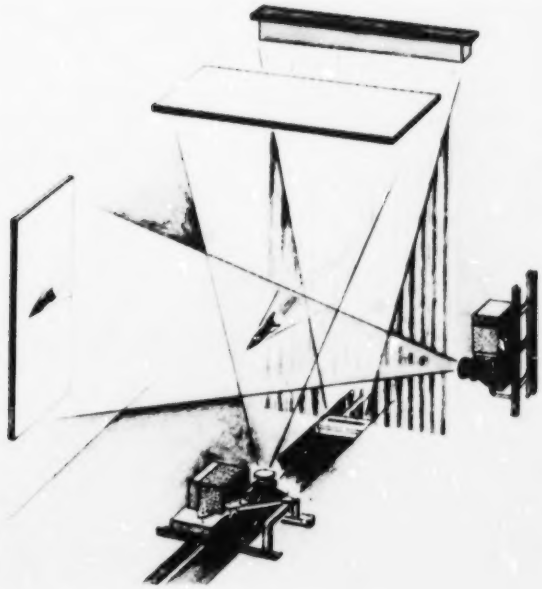


FIGURE 2 - Orthogonal photographic station

2.0 DESIGN CRITERIA

The design of the instrumentation for the aeroballistic range was guided by the following criteria which are based on many years of experience with the operation of ballistic ranges:

1) Electro-Magnetic Interference Insensitivity: the equipment is subjected to the severe environment created by the discharge of numerous electrical energy storage devices and electro-mechanical accessories.

2) Vibration Insensitivity: physical principles used and mechanical supports must make the equipment insensitive to vibration transmitted to the building via the gun support system and the muzzle blast.

3) Cost-Effectiveness: for every model launched, a complete set of data is essential and repeating an experiment is very expensive in terms of time and money.

4) Reliability: since very few personnel are available for checking and servicing the large quantity of equipment to be incorporated in the range, high reliability is essential.

5) Remote Diagnosis: all possible electronic means must be used to remotely test equipment and to identify and report any nonoperating apparatus or accessories which could be responsible for loss of data.

3.0 THE PROJECTILE DETECTOR

Located a short distance uprange of each photographic station, the projectile detector (Fig. 3) consists of a vertical Infrared Radiation (IR) beam generated by incandescent filaments, situated near the ceiling, and detected by an IR sensor on the floor. When a projectile intercepts some of the radiation, the resultant sensor output voltage is amplified and a voltage impulse is fed to the station controller. The detector (Ref. 3) was designed for sensing projectiles of diameters ranging from 7.62 mm to 155 mm travelling in the area covered by both cameras and in which a 150-cm-diameter circle can be inscribed.

The radiation source is a 3-m-long filament consisting of seven 60-W Lumiline lamps (Sylvania L60) connected in parallel to a 115-VDC source. Built from a full-wave rectifier of a three-phase-input power source, the DC source features a 4.6% ripple voltage without filtration. Nevertheless, a filtering circuit was added to reduce ripple to less than 1%. Each unit, Model 260R of Powertronic Equipment Ltd, feeds 18 radiation sources.

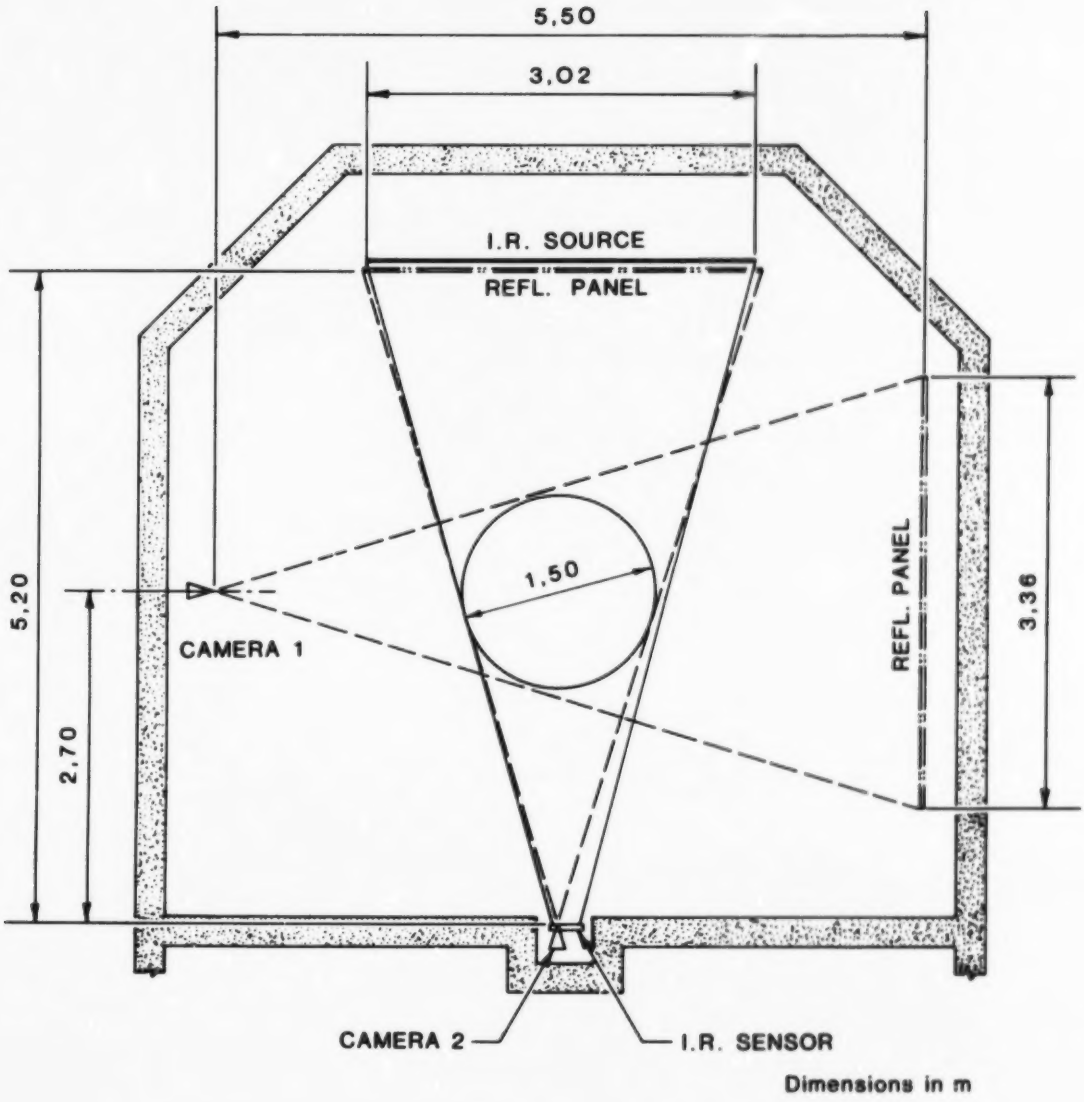


FIGURE 3 - Area of coverage of the projectile detector

In order to minimize the amount of ambient visible radiation in the range that would fog the films when camera shutters are open, an infrared transmitting filter (RG-9 of Schott Optical Glass, Inc, 0.5% transmission at 700 nm and 90% at 800 nm) covers the window of the source assembly.

The IR radiation sensor (Fig. 4) uses a linear array of 11 phototransistors (MOTOROLA MRD-300) mounted 2.54 cm apart on a 25-cm phenolic block. The transistors with a field of view of 20° have their main sensitivity axes fanned to give the 34° total angle of coverage required. The length of the sensor is limited by the width of the floor trough in which it is located. Transistors of equal sensitivity had to be selected to assure a constant sensitivity across the detection area.

3.1 Detector Amplifier

The phototransistors (Fig. 5) convert the sensed radiations into collector currents which are added and amplified in a first operational amplifier. The circuit configuration selected maintains a constant collector-emitter voltage and, therefore, minimizes the collector capacitance effect on output rise time. The first stage of amplification is AC coupled to a second operational amplifier having an adjustable gain ranging from 27 to 220 in four steps. The gain is electrically adjusted to a high value if a small projectile is fired, and is reduced to a lower value for large calibers; this is done in order to make the instrument less sensitive to vibration when large caliber projectiles are fired.

The second operational amplifier is followed by a comparator circuit which compares the amplified signal against a reference voltage that is eight times the noise rms voltage. Whenever a signal of amplitude higher than the reference voltage reaches the comparator input, the latter triggers an impulse-generating circuit which feeds the station controller.

For diagnostic purposes, an additional phototransistor in parallel with the IR detector array is mounted facing a light-emitting diode which is fired by the station controller to simulate the detection of a projectile. This feature permits a verification of the amplifier, the point light sources and the chronograph circuits. As the firing of point light sources can generate transients in the power line, a filter is inserted in series with the power line. A complete schematic of the projectile detector is given in Fig. 6.

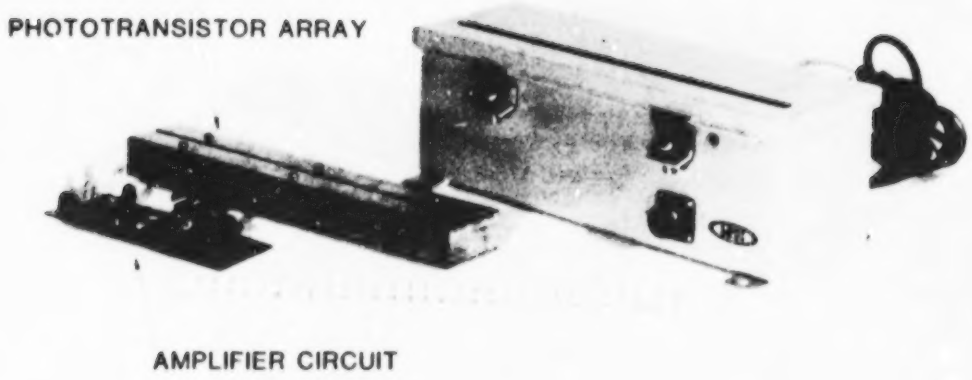


FIGURE 4 - IR radiation detector

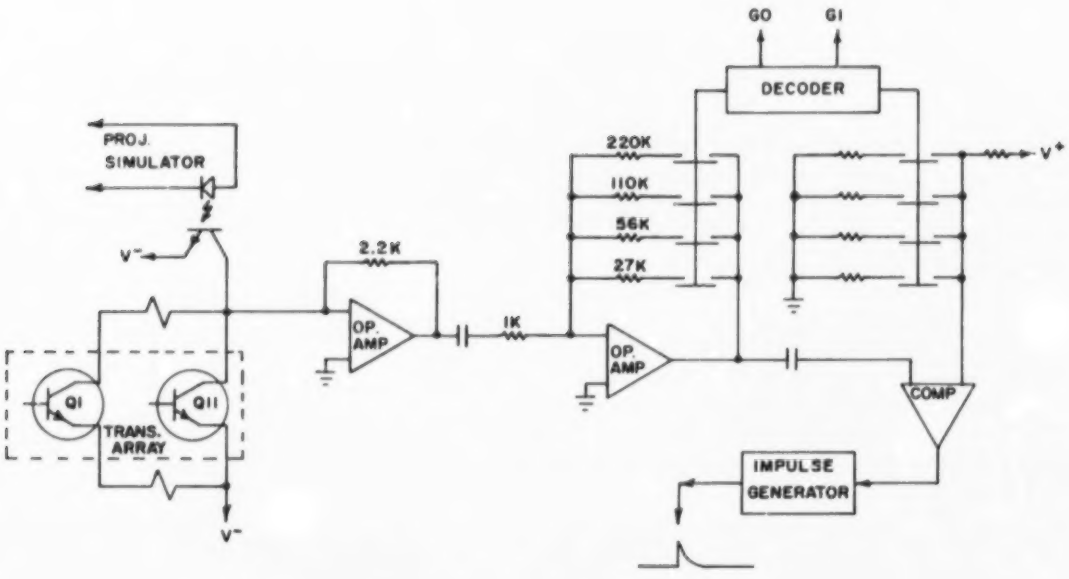
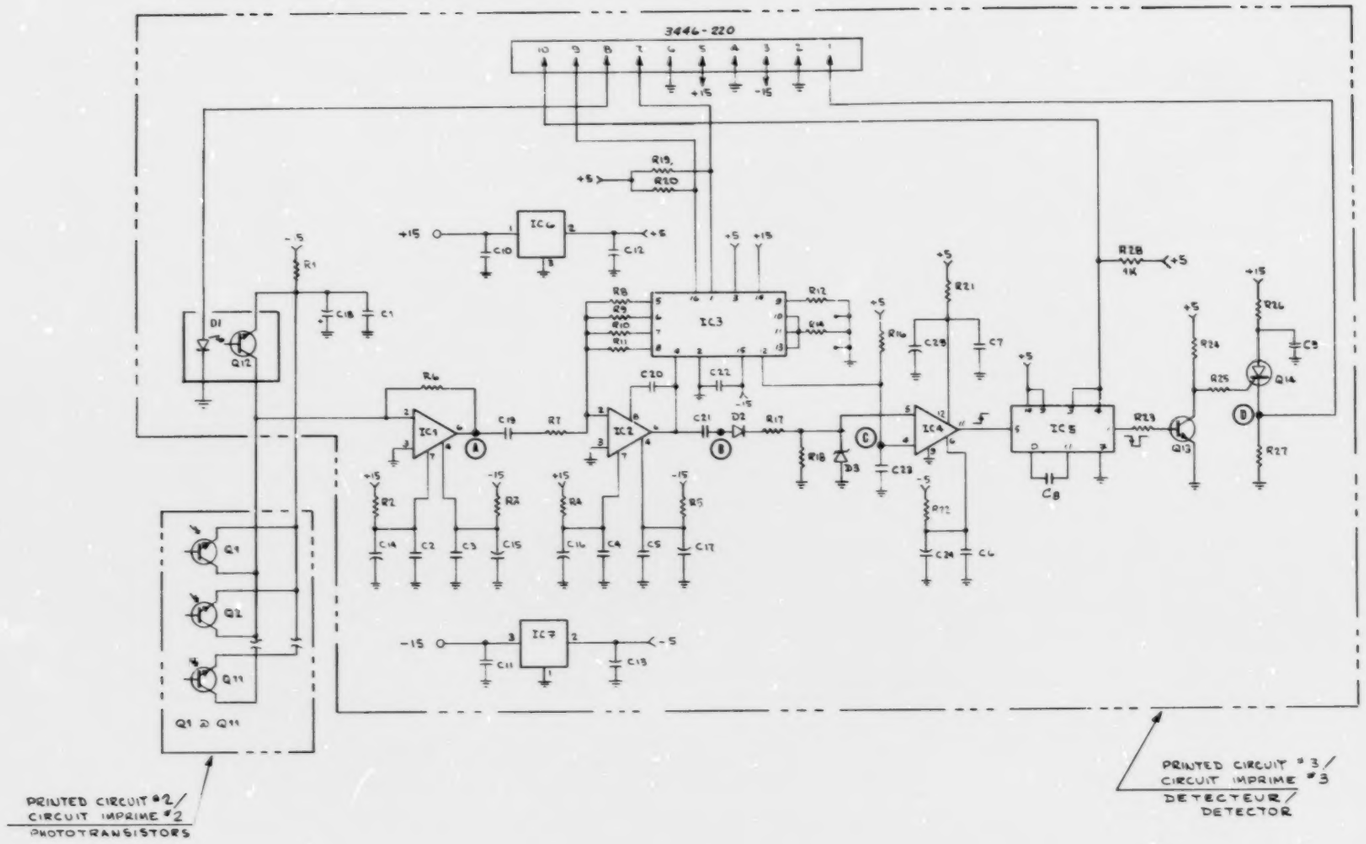
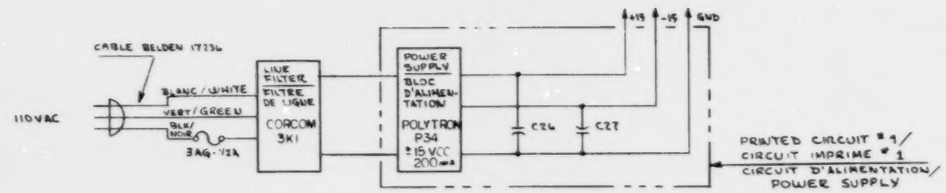


FIGURE 5 - Block diagram of the detector amplifier





LIST OF COMPONENTS
LISTE DES COMPOSANTS

RESISTORS/ RESISTANCES		
R1 à R5	22	Ohms
R6	2.2K	"
R7	1.0K	"
R8	220 K	"
R9	110 K	"
R10	56 K	"
R11	27 K	"
R12	2.2 K	"
R14	1.8 K	"
R16	27 K	"
R17	470	"
R18	10 K	"
R19, R20	1.0K	"
R21	47	"
R22	100	"
R23	1.0K	"
R24	270	"
R25	47	"
R26	47 K	"
R27	47	"
R28	1.0 K	"

CAPACITORS/ CONDENSATEURS		
C1 C8	.01	µF
C9	1	"
C10, C11	.22	"
C12, C13	330	"
C14 à C18	150	"
C19	.47	"
C20	10	Pico Fd
C21, C22, C23	0.1	Micro Fd
C24, C25	10	"
C26, C27	2400	"

SEMICONDUCTORS AND INTEGRATED CIRCUITS/ SEMICONDUCTEURS ET CIRCUITS INTEGRES	
D1	MV5753
D2	1N270
D3	1N746
Q1 à Q12	MRD300
Q13	2N3904
Q14	2N5064
IC1	LF356N
IC2	AM462-2
IC3	AD7502KN
IC4	7600C
IC5	74121N
IC6	7805CT
IC7	7905CT

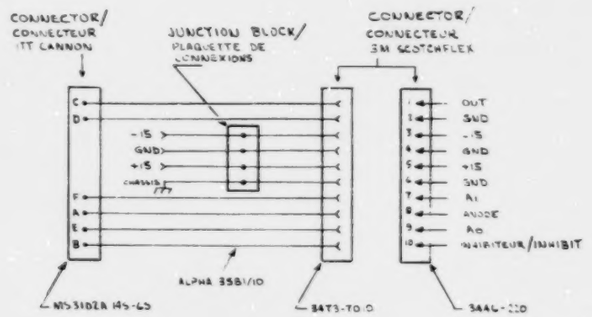


FIGURE 6 - Schematic of the projectile detector

3.2 Detector Characteristics

1) Sensitivity: 7.62-mm to 155-mm projectiles.

2) Gain: electrically adjustable by a factor of 8 in four steps.

3) Angle of field of view: 34°.

4) Amplifier frequency bandwidth: from 0.35 to 45 kHz.

5) Amplifier output rise time: 10 µs.

6) Diagnostic by detection simulation.

7) Immunity to power-line transients.

4.0 THE STATION CONTROLLER

The station controller (Fig. 7) is an intelligent apparatus which controls the operational parameters of the station equipment; that is, of the projectile detector, the cameras and the point light sources. It applies test signals and senses test points in the same equipment to check the state of readiness.

4.1 Controller Functions

For the parent station, the controller performs the following tasks:

1) it sets the gain of the detector amplifier, one of the four levels of gain;

2) it inhibits the triggering of all point light sources of stations further downrange. This feature prevents false triggering of light sources due to electrical or light interference;

3) it triggers the chronographs if this function is selected;

4) it stores the photography delay to be used after projectile detection and triggers the two point light sources. This delay is the time required for the projectile to travel from the detector plane to the center of the photographic station. The delay ranges from 0.01 ms to 9.99 ms;

5) it supplies a train of characters to the cameras for film identification;

6) it sends a test signal to the detector simulation input, and

7) it checks the state of readiness of the equipment by sensing the current in the IR source, the presence of film in the cameras and the open/closed states of camera shutters. Provisions are included for testing additional points.

4.2 Modes of Operation

Two modes of operation can be selected: local or remote. In the local mode, the parameters controlling the station instruments are set on the controller's front panel by the operator and the actual setting, test point status and pulse generation are displayed on visual indicators. This mode is essential for debugging individual stations, testing for interference, etc. In the remote mode, all station controllers are connected in parallel to a communication bus and wait for commands or data from the operator's console. The operator can send data to or request information from individual stations by prefacing the message with an IDXX word, where XX is the station number. Once communication is established, all characters carried on the bus are echoed to the transmitter to make sure that the information has correctly reached an active receiver. Therefore at any given time, only one station controller is linked to the operator's console.

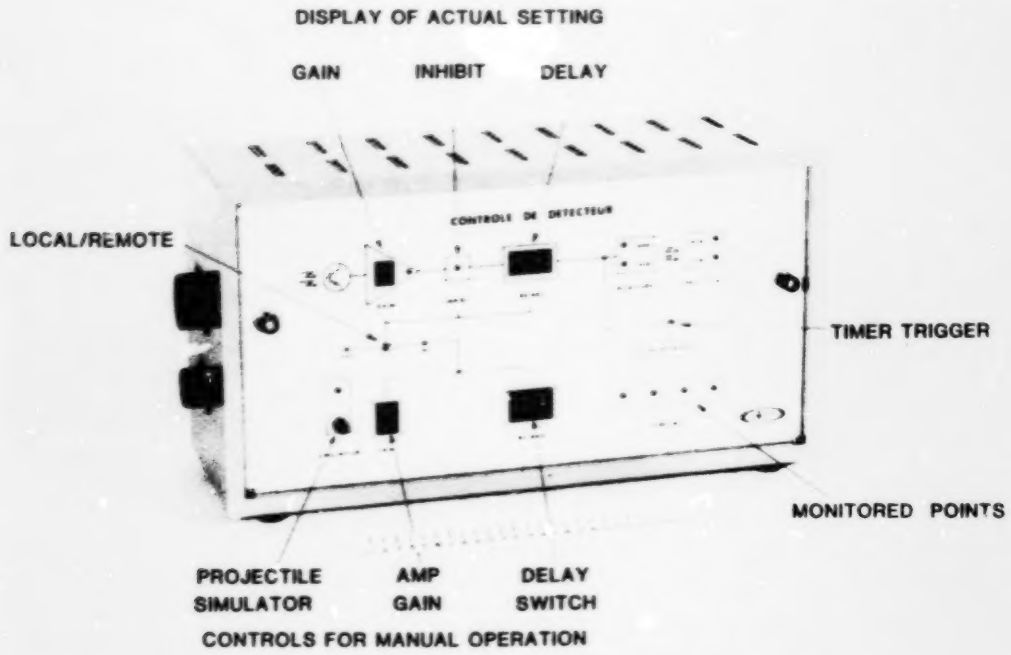


FIGURE 7 - Station controller

4.3 Controller Circuit

A block diagram of the controller circuit, in the remote mode of operation, is shown in Fig. 8. As illustrated, it makes use of a microprocessor, MOTOROLA 6800, tied to standard ROM and RAM memories containing a burn-in program and peripheral adaptors which provide connections to local circuits and switches and interface the controller with the external instruments. Each controller is assigned a unique address and is connected through an ACIA (Asynchronous Communications Interface Adaptor) and three state buffers to a bus that is common to all controllers and to the operator's console. Whenever a message IDXX is carried on the bus, the microprocessor compares its assigned address to the message address XX and, if they match, establishes communication with the operator's console by returning its identification. The console operator can then send data or commands to the controller and have it perform any task described above. Film annotation characters are transmitted to the camera by means of a second ACIA and registers of the Peripheral Interface Adaptor (PIA) are used to control the detector gain, to simulate a detection, to preset the delay counter and to sense the state of a series of test points.

When a trigger pulse is received from the detector and the inhibiting signal from uprange stations is inactive, the counter starts decrementing its count until it reaches zero. Then a trigger is sent to the point light sources and all stations further downrange are inhibited for a period of 0.7 ms. If the inhibiting signal is active, as should happen when any uprange point light source has just fired, the trigger from the projectile detector is not effective. Also included is a switch whereby the operator can choose to record relative time either when light sources are triggered or when they are actually fired. The schematic of the controller is given in Figs. 9 and 10.

5.0 RESULTS OF PRELIMINARY TESTS

Three stations 2.5 m apart were instrumented and tested by firing, in the coverage area, small-caliber projectiles such as standard 7.62-mm bullets and low-velocity 6-mm-diameter spheres to test sensitivity, frequency response and interference due to the proximity of stations. Immunity to building vibration effects due to gun firing was tested by firing 105-mm slugs at a velocity of 1260 m/s and a gun pressure of 160 MPa. Diagnoses were successfully obtained through an Operating System (OS) which controls and reports on the state of the range accessories (such as IR sources, doors, fans and camera shutters), performs a count-down and fires the gun. The equipment satisfied all the required characteristics.

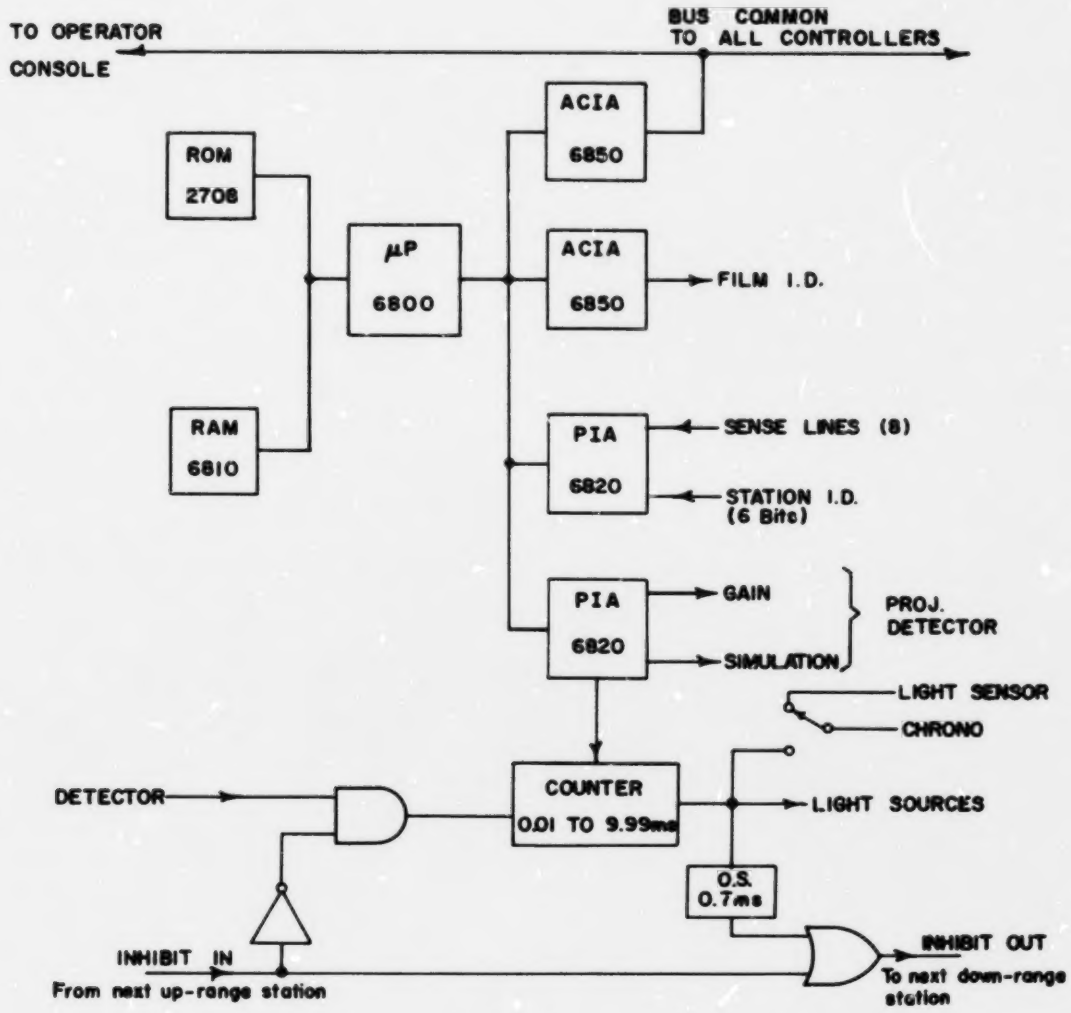


FIGURE 8 - Block diagram of the station controller (in remote mode of operation)

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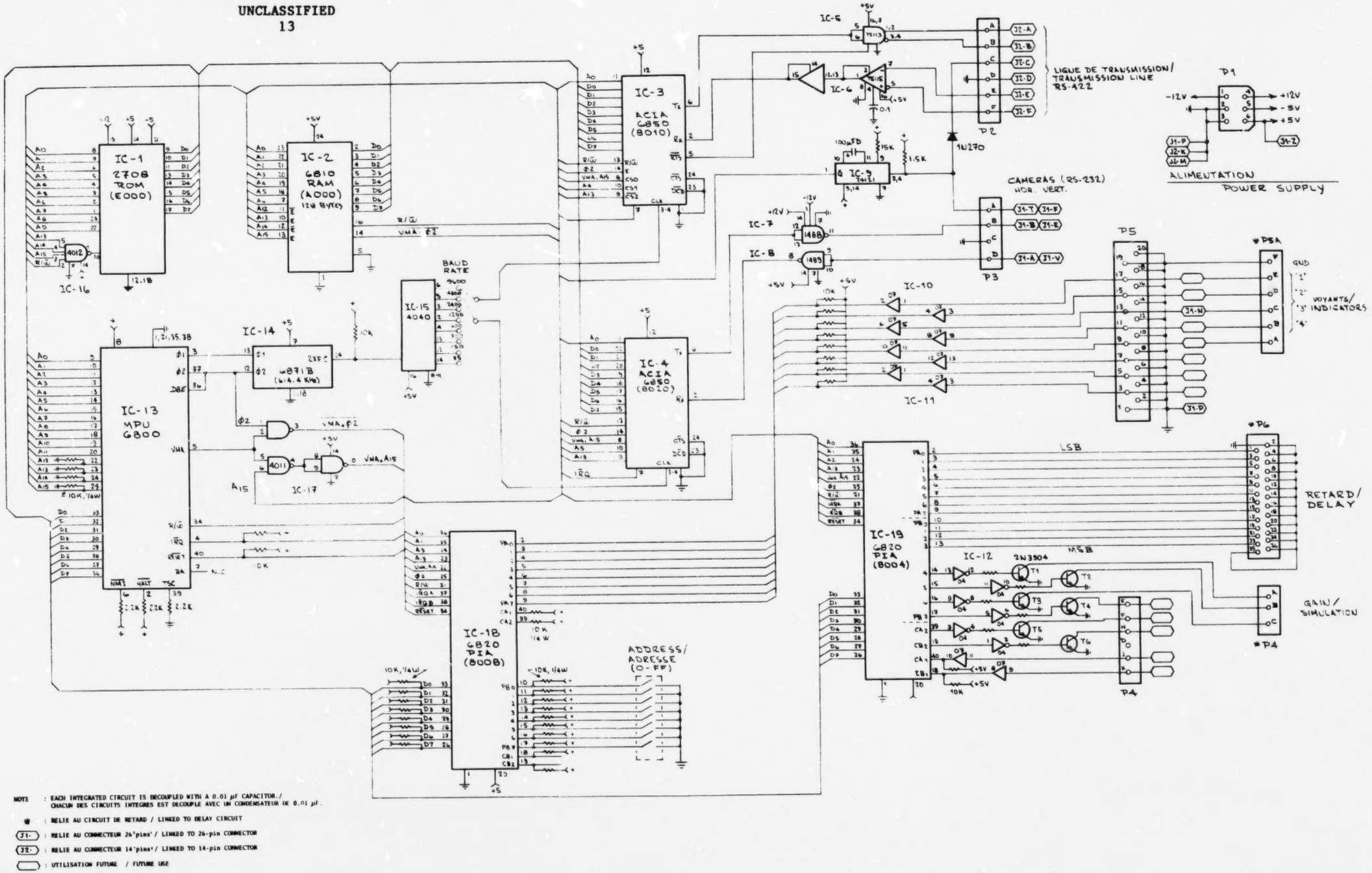

NOTE : EACH INTEGRATED CIRCUIT IS DECOUPLED WITH A 0.01 µF CAPACITOR./
CHACUN DES CIRCUITS INTEGRES EST DECOUPLE AVEC UN CONDENSATEUR DE 0.01 µF.

* : RELIE AU CIRCUIT DE RETARD / LINKED TO DELAY CIRCUIT

(J1-) : RELIE AU CONNECTEUR 26'pins' / LINKED TO 26-pin CONNECTOR

(J2-) : RELIE AU CONNECTEUR 14'pins' / LINKED TO 14-pin CONNECTOR

( ) : UTILISATION FUTURE / FUTURE USE

FIGURE 9 - Schematic of the controller, part one

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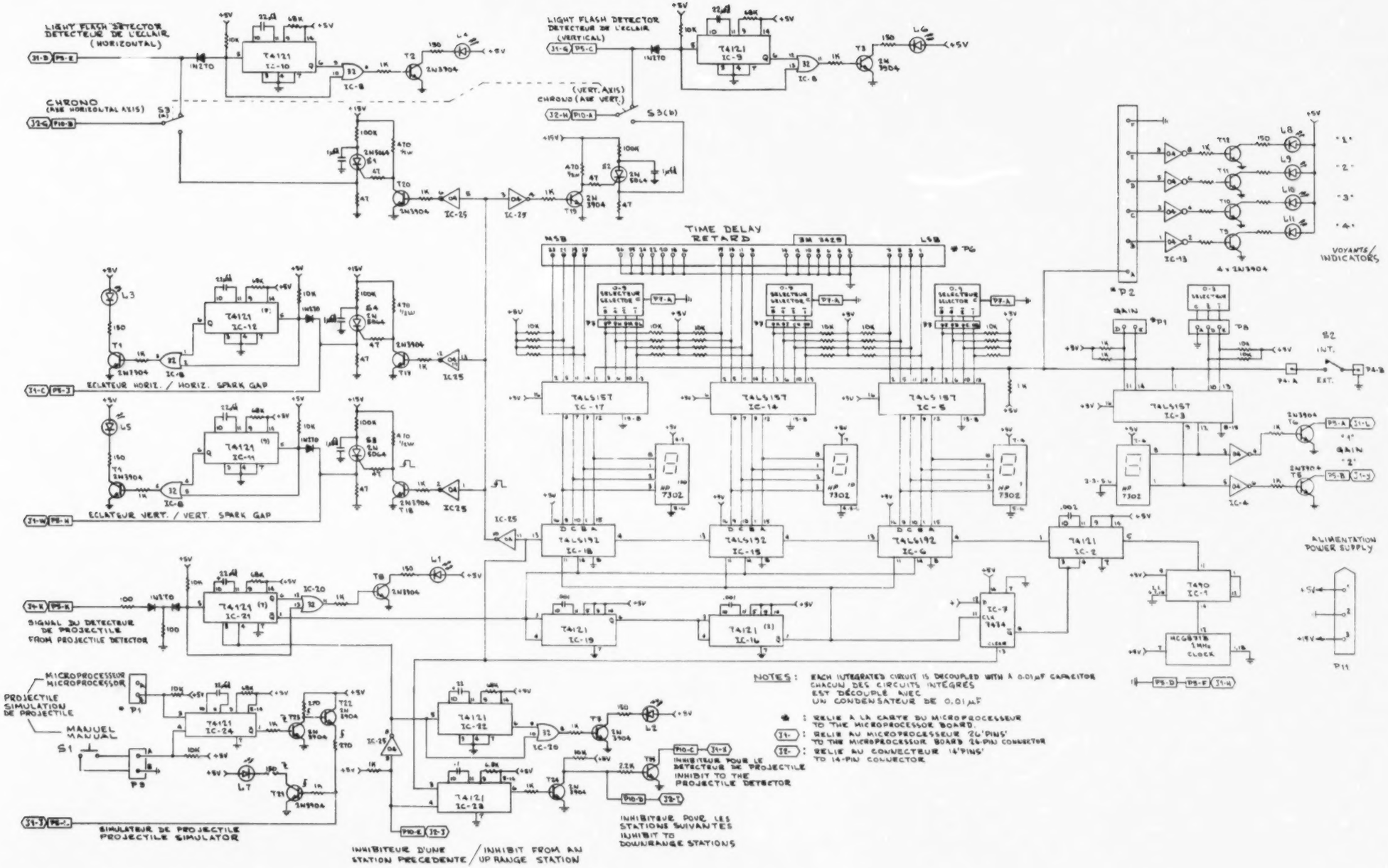

FIGURE 10 - Schematic of the controller, part two

6.0 CONCLUSIONS

The new detector designed for the DREV aeroballistic range facility has been described together with its controller. The availability of low-cost and compact electronics made possible the remote and individual control of the large number of photographic stations. Much emphasis has been given to the automatic testing of equipment and to the reporting of a diagnosis before a model is launched. In particular, each station will be equipped with an intelligent controller to simulate projectile detection and to sense and report on the state of selected accessories. In the past, the lack of such capabilities was often responsible for loss of valuable data. The results of tests performed to the present time indicate that the objectives of this development work have been met.

7.0 ACKNOWLEDGEMENTS

The author would like to express his thanks to Messrs L. Nappert and C. Bradette who designed, built and tested the projectile detector and to Mr. P. Bélanger who was responsible for the design and development of the station controller.

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DREV R-4330/84 (UNCLASSIFIED)

Research and Development Branch, DND, Canada.
DREV, P.O. Box 8800, Courcelette, Que. G0A 1R0

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CRDV R-4330/84 (NON CLASSIFIÉ)

Bureau - Recherche et Développement, MDN, Canada.
CRDV, C.P. 8800, Courcelette, Qué. G0A 1R0

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L'équipement désuet du tunnel aérobalistique du CRDV, qui comprenait une combinaison de postes photographiques et de cartons témoins, est en voie de remplacement par une nouvelle série de 54 postes de photographie orthogonale. A chaque poste, sur deux axes perpendiculaires, une source de lumière ponctuelle projette sur un écran perlé une ombre du projectile laquelle est photographiée par une caméra. A une courte distance en amont du poste un détecteur sensible au passage du projectile informe le contrôleur qui, après un intervalle de temps préréglé, déclenche les sources lumineuses. Tous les contrôleurs sont reliés par un bus commun à la console de l'opérateur et chacun règle le gain du détecteur, le retard de photographie, simule la détection d'un projectile et fournit l'état du poste. Ce rapport traite du détecteur de projectiles et du contrôleur de poste.

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Bureau - Recherche et Développement, MDN, Canada.
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